Adverse Effect of Air Pollution on Respiratory Health of Primary School Children in Taiwan

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This study is a part of the Study On Air Pollution and Health In Taiwan (SOAP&HIT), an ongoing research project involving cooperation of several universities in Taiwan. In this study, the objective was to evaluate the effects of ambient air pollution on respiratory symptoms and diseases of school children, in addition to considering indoor air pollution. Six communities were selected: one community located in a rural area (Taihsi), two in urban areas (Keelung and Sanchung), and the other three in petrochemical industrial areas (Toufen, Jenwu, and Linyuan). We sampled 5,072 primary school students in six communities from the main study population of SOAP&HIT. Respiratory health was assessed by evaluation of the children's respiratory symptoms and diseases using a parent-completed questionnaire. Data were analyzed using logistic regression analysis to compute odds ratios of adverse effect. The school children in the urban communities had significantly more respiratory symptoms (day or night cough, chronic cough, shortness of breath, and nasal symptoms) and diseases (sinusitis, wheezing or asthma, allergic rhinitis, and bronchitis) when compared with those living in the rural community. However, only nasal symptoms of children living in the petrochemical communities were more prevalent than in those living in the rural community. Although the association with ambient air pollution is suggestive, the cross-sectional study cannot confirm a causal relationship; thus further studies are needed. *Key words*: air pollution, cross-sectional study, home dampness, respiratory health, school children. *Environ Health Perspect* 106:331–335 (1998). [Online 11 May 1998]
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In the last few years, several studies have reported significant associations between air pollution and daily mortality and various markers for acute respiratory morbidity, including hospital admissions, hospital emergency and outpatient clinic visits, exacerbation of respiratory symptoms, lung functions changes, and school absenteeism in Europe and America (*1–5*). However, there are still many issues to be clarified before we know the real causal relationship between air pollution and health effects. Specific air pollutants have not been identified as causes of health effects, and effects of short-term peak air pollution exposures are not sufficiently evident. Also, there is no agreement on the economic impact of air pollution-related health effects. To develop the exposure–effect relationship between air pollution and health indices, we cooperated in an ongoing research project, The Study On Air Pollution and Health In Taiwan (SOAP&HIT).

This is the first multicenter (five research institutes), multidisciplinary (health, exposure assessments, statistics, and economics), and multiyear (1994–1997) cross-sectional air pollution study in Taiwan. The SOAP&HIT seeks to address three critical hypotheses: 1) What are the exposure–effect relationships between air pollutant mixtures and various adverse respiratory effects based on population and individualized air pollution exposure data? 2) What are the economic costs for air pollution-related health effects based on the dose–response relationship found in our research? and 3) Is there a subpopulation that is particularly susceptible to air pollution in Taiwan?

To conduct SOAP&HIT efficiently, our disciplinary integrated study design was further classified into four components: exposure assessments, health effects, biological markers, and economic analysis. For efficiency of study design, we decided to use concentrations of three major air pollutants, SO_2, O_3, and particulate matter ≤10 μm (PM_{10}), in the year before this study as indicators to select study sites. A total of eight (2^3) communities were preliminarily selected based on these three pollutants using a factorial design. However, we only selected six out of these communities due to financial constraints. These six sites included different pollution patterns representing rural, urban, and industrial areas in Taiwan.

The objective of the present study was to determine whether there was an adverse effect of air pollution on respiratory health in primary school children. This paper characterizes the respiratory symptoms and diseases of school children in urban and petrochemical communities and in a reference community, which is in a rural area and not in the immediate proximity of any petrochemical or other industrial emissions during the study period.

Materials and Methods

Study design. A cross-sectional survey was designed to determine the prevalence of respiratory symptoms and diseases of primary school children residing in two urban communities exposed to pollution caused by traffic (Keelung and Sanchung), and three petrochemical communities (Toufen, Jenwu, and Linyuan), which serve as the exposed group of stationary sources by petrochemical industries. These communities were compared to a rural community, Taihsi, which serves as the reference group in Taiwan (Table 1). According to population characteristics and air pollution patterns (*6*), the three petrochemical communities were classified further: both Toufen and Jenwu also had traffic pollution, the populations are ethnically Hakka in Toufen and Taiwanese in Jenwu, and Linynan represents typical petrochemical pollution.

Subjects. Among 5,072 primary school students selected from the six communities, a total of 4,860 returned the questionnaire, for a response rate of 95.8%. Of this group of children, 81.6% had resided in their current houses for at least 3 years. Questionnaires with incomplete data (136) were excluded for the purpose of consistency throughout the analyses. A total of 4,697 valid questionnaires are presented in this study (Table 2).

Air monitoring. The hourly concentrations of nine air pollutants including PM_{10}, SO_2, NO_X, NO, NO_2, O_3, total hydrocarbons (THC), nonmethane hydrocarbons (NMHC), and CO are continuously monitored and carried out by the Environmental

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Table 1. The design structure of the Study On Air Pollution and Health In Taiwan

	Rural area	Urban areas		Petrochemical industrial areas		
Site	Taihsi	Keelung	Sanchung	Toufen	Jenwu	Linyuan
Population density (persons/km^2)	568	13,670	23,115	1,568[a]	2,174	1,238
Study population	Taihsi primary school children (705)[b]	Jenai primary school children (954)	Shuder primary school children (1,386)	Luiho primary school children (796)	Bakua primary school children (701)	Sanwei primary school children (530)
Air monitoring	Nine air pollutants[c] excluding HC	Nine air pollutants	Nine air pollutants excluding HC	Nine air pollutants excluding CO and O_3	Nine air pollutants	Nine air pollutants
Exposure assessment	IAQ questionnaire	IAQ questionnaire	IAQ questionnaire	IAQ questionnaire	IAQ questionnaire	IAQ questionnaire
Health effect	Symptoms (657)	Symptoms (917)	Symptoms (1,326)	Symptoms (771)	Symptoms (689)	Symptoms (500)

Abbreviations: HC, hydrocarbons; IAQ, indoor air quality; PM_{10}, particulate matter ≤10 μm; THC, total HC; NMHC, nonmethane HC.

[a]The population is ethnically Hakka.

[b]Values in parentheses are number sampled.

[c]Nine air pollutants include SO_2, CO, O_3, PM_{10}, NO_X, NO, NO_2, THC, and NMHC.

Protection Administration air quality monitoring stations located in the campus of the selected primary school in each community. The instrumentation used in the fixed-site monitoring stations are β-gauge for PM_{10}; UV fluorescence for SO_2; chemiluminescence for NO_X, NO, and NO_2; flame ionization for THC and NMHC; non-disperse infrared absorption for CO; and UV absorption for O_3. The air quality was measured by comparing the air pollution levels with appropriate National Ambient Air Quality Standards (NAAQS) for each air pollutant. Two-year monitoring data from 1994 to 1995 are included in this study. In the preliminary analysis, the six public schools were similar with respect to indoor environment and timetable for teaching activity.

Questionnaire. A respiratory health questionnaire was distributed through the schools to the children in December 1994. The questionnaire was completed by parent or guardian and returned to the school. One nurse for each school distributed and collected the questionnaires. The questionnaire used in this study was mainly adapted and modified from the World Health Organization (WHO) childhood respiratory questionnaire (*7*). The questionnaire was divided into the following five parts: demographic data, respiratory symptoms and diseases of the children, housing conditions, children's bedrooms, and possible sources of indoor air pollution such as household smoking, pets, fowls, coal stove used, tea gas-cooker used, incense burning the whole day, mosquito repellent burning, indoor plants, and home dampness. The dose gradient for home dampness was defined as the presence of any visible mold or its stuffy odor in the rainy season (usually about 3 months/year between April and June) only, when it is cloudy or rains on several consecutive days only, or on most days.

In this paper, we defined morning cough as cough usually in the morning, day

Table 2. Study population by gender, grade, and father's education

	Rural area	Urban areas		Petrochemical industrial areas			
Study population	Taihsi	Keelung	Sanchung	Toufen	Jenwu	Linyuan	Total
Total	705	954	1,386	796	701	530	5,072
Responses	657 (95.3)	917 (96.1)	1,326 (95.9)	771 (96.9)	689 (98.4)	500 (94.2)	4,860 (95.8)
Valid responses	611 (86.7)	895 (93.8)	1,298 (93.7)	748 (94.0)	675 (96.3)	470 (88.7)	4,697 (96.6)
Sex							
Male	292 (47.8)	464 (51.8)	663 (51.1)	356 (47.6)	351 (52.0)	245 (52.1)	2371 (50.5)
Female	319 (52.2)	431 (48.2)	635 (48.9)	392 (52.4)	324 (48.0)	225 (47.9)	2,326 (49.5)
School grade							
Low (1–2)	170 (27.8)	254 (28.4)	399 (30.7)	228 (30.5)	206 (30.5)	130 (27.7)	1,387 (29.5)
Middle (3–4)	221 (36.2)	315 (35.2)	381 (29.4)	231 (30.9)	215 (31.9)	131 (27.9)	1,494 (31.8)
High (5–6)	220 (36.0)	326 (36.4)	518 (39.9)	289 (38.6)	254 (37.6)	209 (44.5)	1,816 (38.7)
Father's education							
Primary school	194 (31.8)	57 (6.4)	328 (25.3)	75 (10.0)	180 (26.7)	251 (53.4)	1,085 (23.1)
Junior school	228 (37.3)	120 (13.4)	354 (27.3)	199 (26.6)	211 (31.3)	121 (25.7)	1,233 (26.3)
High school	136 (22.3)	415 (46.4)	424 (32.7)	344 (46.0)	219 (32.4)	71 (15.1)	1609 (34.3)
University	38 (6.2)	286 (32.0)	168 (12.9)	117 (15.6)	48 (7.1)	17 (3.6)	674 (14.3)
Unknown	15 (2.5)	17 (1.9)	24 (1.8)	13 (1.7)	17 (2.5)	10 (2.1)	96 (2.0)
Mother's education							
Primary school	320 (52.4)	95 (10.6)	407 (31.4)	113 (15.1)	230 (34.1)	290 (61.7)	1,455 (31.0)
Junior school	160 (26.2)	135 (15.1)	377 (29.0)	326 (43.6)	237 (35.1)	123 (26.2)	1,358 (28.9)
High school	91 (14.9)	490 (54.7)	401 (30.9)	273 (36.5)	183 (27.1)	41 (8.7)	1,479 (31.5)
University	27 (4.4)	166 (18.5)	86 (6.6)	26 (3.5)	13 (1.9)	5 (1.1)	323 (6.9)
Unknown	13 (2.1)	9 (1.0)	27 (2.1)	10 (1.3)	12 (1.8)	11 (2.3)	82 (1.7)

Values in parentheses are percent.

Table 3. Average concentrations (AC) and days of exceedance (DE) for five criteria air pollutants during 1994–1995

	Rural area		Urban areas				Petrochemical industrial areas					
	Taihsi		Keelung		Sanchung		Toufen		Jenwu		Linyuan	
Pollutant	AC	DE	AC	DE	AC	DE	AC	DE	AC	DE	AC	DE
SO_2[a] (ppb)	3.27	0	8.68	0	8.77	0	45.79	108	17.20	0	16.04	0
CO (ppm)	0.40	0	0.93	0	1.35	0	NM	NM	0.76	0	0.66	0
O_3[b] (ppb)	52.56	2	41.90	0	38.34	0	NM	NM	52.12	2	60.64	26
PM_{10}[c] (μg/m^3)	72.20	57	53.42	6	66.76	44	64.31	19	95.67	197	109.97	294
NO_2 (ppb)	10.00	0	25.41	0	31.84	0	25.83	0	29.32	0	20.15	0

Abbreviations: NM, not measured; PM_{10}, particulate matter ≤10 μm..

[a]Daily SO_2 average >100 ppb.

[b]Daytime average and hourly O_3 average >120 ppb.

[c]Daily PM_{10} average >125 μg/m^3.

or night cough as cough usually in the rest of the day or at night, and chronic cough as the previous symptoms on most days for 3 consecutive months or more during the year. We defined shortness of breath as breathlessness when hurrying on the level or walking up a slight hill and wheezing as a wheezy or whistling sound in the chest at any time. Nasal symptoms were defined as stuffy and running nose or sneezing in the morning or before sleeping, apart from colds for 2 or 3 consecutive days or more. Self-reported respiratory diseases such as sinusitis, wheezing or asthma, allergic rhinitis, bronchitis, and pneumonia were included in a history of respiratory disease diagnosed by medical doctors.

Statistics. We analyzed data concerning the prevalence of respiratory symptoms and diseases according to place of residence. To explore the relationship between respiratory symptoms and diseases and the exposure areas, multiple logistic regression models were used in which the potential confounding factors were controlled. The adjusted odds ratios (aORs) and their 95% confidence intervals (CIs) were computed. All statistical analyses were performed using the SPSS for Windows, Release 6.1. (8,9).

Results

As indicated in Table 3, both mean concentrations and exceedance frequencies were significantly different for most air pollutants among the three community types. For two mixed-type communities (Toufen and Jenwu) and the typical petrochemical community (Linyuan), their average SO_2 concentrations (16–46 ppb) were significantly higher than rural (3 ppb) and urban (9 ppb) communities. As expected, the average concentrations of CO in two urban communities (0.9–1.4 ppm) were significantly higher than the concentrations in both the rural (0.4 ppm) and the typical petrochemical (0.7 ppm) communities. For NO_2, the average concentrations in rural communities (10 ppb) were significantly lower than those in typical petrochemical (20 ppb), urban (25–32 ppb), and mixed-type (26–29 ppb) communities. The concentrations of O_3 and PM_{10} also show interesting comparisons among these six communities. The lowest concentrations for both air pollutants were found in the two urban communities of Keelung and Sanchung (38–42 ppb for O_3 and 53–67 μg/m^3 for PM_{10}), while the highest concentrations were in the two petrochemical communities of Jenwu and Linyuan (52–60 ppb for O_3 and 96–110 μg/m^3 for PM_{10}).

The basic information of the study population is shown in Table 2. With regard to the children's sex, there was no significant difference among those living in different communities. The proportion of children (44.5%) who were in high grades (grades 5 and 6) in the typical petrochemical industrial community (Linyuan) was slightly higher than proportions in the other communities. However, there were apparent differences in education of the children's parents. For example, education of fathers in Linyuan community was the lowest level on average of those in the six communities.

Table 4. Prevalence of respiratory symptoms and diseases

	Rural area	Urban areas		Petrochemical industrial areas			
Respiratory condition	Taihsi	Keelung	Sanchung	Toufen	Jenwu	Linyuan	Total
Symptoms							
Morning cough	70 (11.5)	122 (13.6)	175 (13.5)	83 (11.1)	81 (12.0)	64 (13.6)	595 (12.7)
Day or night cough	61 (10.0)	116 (13.0)	188 (14.5)	79 (10.6)	82 (12.1)	63 (13.4)	589 (12.5)
Chronic cough	17 (2.8)	42 (4.7)	72 (5.5)	29 (3.9)	17 (2.5)	14 (3.0)	191 (3.9)
Shortness of breath	69 (11.3)	114 (12.7)	196 (15.1)	87 (11.6)	78 (11.6)	46 (9.8)	590 (12.6)
Nasal symptoms	121 (19.8)	292 (32.6)	404 (31.1)	166 (22.2)	182 (27.0)	131 (27.9)	1,296 (27.6)
Diseases							
Sinusitis	38 (6.2)	104 (11.6)	103 (7.9)	39 (5.2)	49 (7.3)	28 (6.0)	361 (7.7)
Wheezing or asthma	34 (5.6)	89 (9.9)	109 (8.4)	29 (3.9)	36 (5.3)	30 (6.4)	327 (7.0)
Allergic rhinitis	53 (8.7)	175 (19.6)	200 (15.4)	70 (9.4)	74 (11.0)	36 (7.7)	608 (12.9)
Bronchitis	98 (16.0)	269 (30.1)	342 (26.3)	170 (22.7)	115 (17.0)	77 (16.4)	1,071 (22.8)
Pneumonia	21 (3.4)	31 (3.5)	40 (3.1)	15 (2.0)	11 (1.6)	18 (3.8)	136 (2.9)
Family's respiratory diseases	73 (11.9)	153 (17.1)	206 (15.9)	87 (11.6)	84 (12.4)	39 (8.3)	642 (13.7)
Total subjects (*n*)	611	895	1,298	748	675	470	4,697

Values in parentheses are percent.

Table 5. Indicators of indoor environment

	Rural area	Urban areas		Petrochemical industrial areas			
Indoor condition	Taihsi	Keelung	Sanchung	Toufen	Jenwu	Linyuan	Total
Crowding index							
Low (≥10 m^2/person)	437 (71.5)	830 (92.7)	1,119 (86.2)	670 (89.6)	533 (79.0)	354 (75.3)	3,943 (83.9)
High (<10 m^2/person)	98 (16.0)	40 (4.5)	128 (9.9)	41 (5.5)	99 (14.7)	62 (13.2)	468 (10.0)
Unknown	76 (12.4)	25 (2.8)	51 (3.9)	37 (4.9)	43 (6.4)	54 (11.5)	286 (6.1)
Household smoking							
None	161 (26.4)	357 (39.9)	468 (36.1)	225 (30.1)	214 (31.7)	128 (27.2)	1,553 (33.1)
Low (≤1 pack/day)	380 (62.2)	500 (55.9)	766 (59.0)	455 (60.8)	422 (62.5)	295 (62.8)	2,818 (60.0)
High (1+ pack/day)	36 (5.9)	19 (2.1)	35 (2.7)	38 (5.1)	18 (2.7)	30 (6.4)	176 (3.7)
Unknown amount	34 (5.6)	19 (2.1)	29 (2.2)	30 (4.0)	21 (3.1)	17 (3.6)	150 (3.2)
Pets	149 (24.4)	178 (19.9)	287 (22.1)	238 (31.8)	194 (28.7)	136 (28.9)	1,182 (25.2)
Fowls	186 (30.4)	66 (7.4)	117 (9.0)	174 (23.3)	120 (17.8)	126 (26.8)	789 (16.8)
Coal stove used	10 (1.6)	–	3 (0.2)	2 (0.3)	3 (0.4)	7 (1.5)	25 (0.5)
Tea gas-cooker used	205 (33.6)	69 (7.7)	134 (10.3)	66 (8.8)	84 (12.4)	62 (13.2)	620 (13.2)
Incense burning the whole day	34 (5.6)	21 (2.3)	41 (3.2)	14 (1.9)	13 (1.9)	15 (3.2)	138 (2.9)
Mosquito repellent burning	269 (44.0)	213 (23.8)	280 (21.1)	300 (40.1)	316 (46.8)	229 (48.7)	1,607 (34.2)
Indoor plants	200 (32.7)	237 (26.5)	439 (33.8)	284 (38.0)	227 (33.6)	128 (27.2)	1,515 (32.3)
Home dampness							
None	402 (65.8)	390 (43.6)	802 (61.8)	401 (53.6)	382 (56.6)	271 (57.7)	2,648 (56.4)
In rainy season	142 (23.2)	350 (39.1)	328 (25.3)	231 (30.9)	193 (28.6)	108 (23.0)	1,352 (28.8)
When continuously raining	49 (8.0)	129 (14.4)	151 (11.6)	98 (13.1)	92 (13.6)	72 (15.3)	591 (12.6)
On most days	18 (2.9)	26 (2.9)	17 (1.3)	18 (2.4)	8 (1.2)	19 (4.0)	106 (2.3)
Total subjects (*n*)	611	895	1298	748	675	470	4,697

Values in parentheses are percent.

The reported prevalences of respiratory symptoms and diseases are summarized in Table 4. Children living in the urban area (Keelung and Sanchung) had consistently higher rates of respiratory symptoms and diseases (with the exception of pneumonia) than did those living in the rural community (Taihsi). However, nasal symptoms were more prevalent in children living in the petrochemical communities (Toufen, Jenwu, and Linyuan) than in the rural community. For morning cough and day or night cough, there was a steady rise with the Hakka (Toufen), mixed (Janwu), and typical (Linyuan) petrochemical industrial communities.

Table 5 shows the conditions of the indoor environment of the study subjects. There were obvious differences among children living in different communities with

Table 6. Adjusted odds ratios (95% confidence intervals) for respiratory symptoms and diseases by air pollution patterns compared to the rural area

		Petrochemical industrial areas		
Respiratory condition	Urban areas	Toufen	Jenwu	Linyuan
Symptoms				
Morning cough	1.33 (0.98–1.80)	0.96 (0.67–1.37)	1.09 (0.76–1.55)	1.17 (0.80–1.71)
Day or night cough	1.67 (1.21–2.29)**	1.13 (0.77–1.64)	1.35 (0.94–1.95)	1.38 (0.93–2.04)
Chronic cough	1.88 (1.07–3.31)*	1.26 (0.66–2.41)	0.88 (0.44–1.79)	1.08 (0.51–2.26)
Shortness of breath	1.40 (1.04–1.91)*	1.01 (0.71–1.44)	1.05 (0.74–1.51)	0.80 (0.54–1.21)
Nasal symptoms	1.96 (1.54–2.48)##	1.17 (0.88–1.54)	1.59 (1.21–2.09)#	1.59 (1.19–2.14)**
Diseases				
Sinusitis	1.53 (1.04–2.26)*	0.76 (0.47–1.23)	1.18 (0.75–1.87)	0.98 (0.59–1.65)
Wheezing or asthma	1.68 (1.11–2.54)*	0.63 (0.37–1.07)	0.97 (0.59–1.60)	1.16 (0.69–1.96)
Allergic rhinitis	1.82 (1.31–2.52)#	0.94 (0.64–1.40)	1.25 (0.85–1.84)	0.90 (0.57–1.42)
Bronchitis	1.72 (1.33–2.23)##	1.23 (0.91–1.65)	1.01 (0.74–1.38)	1.17 (0.83–1.64)
Pneumonia	1.10 (0.63–1.92)	0.62 (0.31–1.26)	0.53 (0.25–1.13)	1.21 (0.62–2.36)
Family's respiratory diseases	1.40 (1.04–1.89)*	0.82 (0.58–1.17)	1.03 (0.73–1.46)	0.70 (0.46–1.08)

Values have been adjusted for gender, school grade, father's education, crowding index, household smoking, pets, fowls, coal stove used, tea gas-cooker used, incense burning the whole day, mosquito repellent burning, indoor plants, and home dampness using logistic models.
*$p<0.05$; **$p<0.01$; #$p<0.001$; ##$p<0.0001$.

regard to the level of crowding, the amount of household smoking in the dwelling, the presence of feathered or hairy pets, fowls kept in the home, the use of a coal stove, the use of a tea gas-cooker in the home, the burning of incense the whole day, the burning of a mosquito repellent, plants inside the home, and self-reported home dampness. Children in Taihsi, Jenwu, and Linyuan lived in more crowded households than did those in the other communities. The amount of household smoking in Taihsi and Linyuan was higher than in the other communities. Home dampness was reported more frequently in Keelung.

The results of the logistic regression analysis are shown in Table 6. The school children in the urban communities (Keelung and Linyuan) had higher risks of having respiratory symptoms (day or night cough, chronic cough, shortness of breath, and nasal symptoms) or diseases (sinusitis, wheezing or asthma, allergic rhinitis, and bronchitis) when compared with those living in the rural community (Taihsi). For example, compared to children in the rural community, children in the urban communities had a higher risk of having day or night cough (aOR = 1.67; CI, 1.21–2.29), chronic cough (aOR = 1.88; CI, 1.07–3.31), shortness of breath (aOR = 1.40; CI, 1.04–1.91), and nasal symptoms (aOR = 1.96; 95% CI, 1.54–2.48). On the other hand, children living in the petrochemical communities (Jenwu and Linyuan) had higher odds of having nasal symptoms than did those living in the rural community. Compared to children in the rural community, children in the petrochemical industrial communities had a higher risk of having nasal symptoms (mixed type: aOR = 1.59; CI, 1.21–2.09 and typical: aOR = 1.59; CI, 1.19–2.14).

Among indicators of indoor environment, home dampness was the most significant factor in relation to children's respiratory health. The crowding index, household smoking, pets, fowls, use of a coal stove, use of a tea gas-cooker, incense burning the whole day, mosquito repellent burning, and indoor plants are also significantly associated with some of respiratory symptoms and diseases. There were dose–response relationships between home dampness and most of the respiratory symptoms and diseases after controlling for the potential confounders mentioned above (see Table 7). For example, compared to children whose parent did not report any sign of dampness in the home, children with reported home dampness had a higher risk of having morning cough, which increased with an increase in dampness (dampness in rainy season: aOR = 1.62; CI, 1.32–1.98; dampness with continuous rain: aOR = 2.22; CI, 1.74–2.84; and dampness on most days: aOR = 3.30; 95% CI, 2.09–5.19).

Discussion

The school children in the urban communities had significantly more respiratory symptoms (day or night cough, chronic cough, shortness of breath, and nasal symptoms) and diseases (sinusitis, wheezing or asthma, allergic rhinitis, and bronchitis) when compared with those living in the rural community. On the other hand, nasal symptoms were more prevalent in children living in the petrochemical communities than in those living in the rural community.

When evaluating the effects of individual sources of pollution, an epidemiologic approach best eliminates the effects of other variables (*10*). Unfortunately, such an approach is impossible in this cross-sectional survey. In this study, we evaluated the health effects in six communities with different pollution patterns, based on community monitoring (*6*). We used a spatial approach in which multivariate statistical analyses were performed to control for possible confounding factors.

Because there are several types of health care in Taiwan, including Western, Chinese, and herbal medicine and self-medication bought from drug stores, we could not use medical records from general practice only. Thus, we selected respiratory symptoms of primary school children as indices of health effects resulting from air pollution. Parents of the subjects completed questionnaires concerning the status of the children's respiratory health. The limitations of this type of research tool have been reviewed (*11*), and reporting errors may have occurred in this study. All questions concerning respiratory health were selected from a standardized questionnaire (*7*).

This cross-sectional study offers weak evidence for causality because one cannot be confident that exposure preceded the disease. Most of the children in this study had lived in their current houses for at least 3 years, although the etiologically meaningful time between exposure and occurrence of respiratory symptoms and disease is still a matter of debate. The overall high response rate achieved in the present study increases confidence in the data and makes an important selection bias unlikely. Also, we collected the data in the same month in order to avoid differential inclusion of study subjects into the survey according to season, which can bias the results.

The study communities included rural, urban, and petrochemical industrial areas and therefore may have shown apparent differences in socioeconomic status. In this study, the father's education at a primary school level gave lower odds for chronic cough, allergic rhinitis, and bronchitis (more severe respiratory conditions) than those at higher educational levels. We concluded that these respiratory conditions in questionnaires were underreported by parents or guardians at low levels of education. The father's education as a surrogate was included in the final models to control for differences of health-care seeking behavior and disease perception.

Hakka people (Toufen) are known for their hard work and high tolerance to difficult or hazardous environments. They may be less likely to express their complaints of bodily discomfort or they may have a higher threshold of discomfort to consider it a symptom. Our results in Tables 4 and 6 show this trend before and after controlling for indoor air pollution, compared to the

Table 7. Adjusted odds ratios (95% confidence intervals) for respiratory symptoms and diseases by home dampness

Respiratory condition	In raining season	When continuously raining	On most days
Symptoms			
Morning cough	1.62 (1.32–1.98)##a	2.22 (1.74–2.84)##	3.30 (2.09–5.19)##
Day or night cough	1.62 (1.32–1.98)##	2.13 (1.67–2.73)##	2.92 (1.82–4.68)##
Chronic cough	2.72 (1.93–3.83)##	2.75 (1.80–4.19)##	2.33 (0.97–5.62)
Shortness of breath	1.90 (1.56–2.32)##	2.08 (1.62–2.69)##	3.35 (2.10–5.34)##
Nasal symptoms	1.33 (1.15–1.55)#	1.74 (1.44–2.12)##	2.58 (1.72–3.86)##
Diseases			
Sinusitis	1.12 (0.86–1.45)	1.90 (1.41–2.55)##	2.26 (1.26–4.04)**
Wheezing or asthma	1.56 (1.20–2.01)#	1.54 (1.10–2.16)*	1.57 (0.79–3.13)
Allergic rhinitis	1.13 (0.92–1.38)	1.72 (1.34–2.20)##	2.24 (1.35–3.70)**
Bronchitis	1.79 (1.52–2.10)##	2.48 (2.02–3.05)##	1.74 (1.10–2.76)*
Pneumonia	1.36 (0.91–2.05)	1.96 (1.22–3.13)**	2.77 (1.21–6.32)*
Family's respiratory diseases	1.60 (1.31–1.94)##	2.39 (1.88–3.03)##	2.06 (1.24–3.42)**

[a]Adjusted for gender, school grade, fatherís education, crowding index, household smoking, pets, fowls, coal stove used, tea gas-cooker used, incense burning the whole day, mosquito repellent burning, indoor plants, and air pollution patterns using logistic models.
*$p<0.05$; **$p<0.01$; #$p<0.001$; ##$p<0.0001$.

other two schools located in petrochemical industrial area.

The study communities were located in different regions of Taiwan and therefore exhibited differences in indoor air pollution. However, it is unlikely that there were major disparities in indoor air pollution because data on a number of known or potential determinants of indoor air pollution were collected and adjusted for, including household smoking in the dwelling and exposure to other major potential sources.

The observed high prevalence of home dampness and mold indicated that dampness in the home was very common in the subtropical region studied, and home dampness was a strong predictor of respiratory symptoms (*12*). The prevalence of most of the reported respiratory conditions was found to be higher (day or night cough, chronic cough, shortness of breath, and bronchitis significantly so) among children whose fathers or mothers were smokers, compared with children of nonsmoking parents. The effect of parental smoking is in accordance with the literature (*13*).

This study was cross-sectional in design and, although it shows that respiratory symptoms and diseases were significantly more common among children from the urban communities, it may not be attributed to a specific pollutant. Particulate SO_2, NO_2, and acid aerosols have been associated with increased prevalences of these respiratory symptoms in children (*14–17*). The concentrations of NO_2 and CO in these two urban communities were apparently higher than those in the rural community. Thus, exposure to NO_2 may contribute to increased risks of respiratory diseases, but the result is probably also related to traffic pollution mixtures (*18,19*).

On the other hand, only irritant symptoms, such as nasal symptoms other than colds, were significantly more prevalent among children from the petrochemical communities where SO_2 was evidently higher than in the rural community. These pollutants may explain the higher prevalences of nasal symptoms in the petrochemical communities; however, increased levels of one pollutant (such as SO_2) are often associated with high concentrations of other pollutants, such as particulate and acid aerosols. Therefore, the contribution of each compound to impaired respiratory health remains inconclusive.

Exposure to a mixture of air pollutants from mobile sources may be associated with adverse respiratory health of the children living in the urban areas, but air pollutants predominantly from the petrochemical industrial areas may only induce nasal irritation symptoms. Although the association with known air pollutants is suggestive, a cross-sectional study cannot confirm a causal relationship and further studies are needed to determine the exposure–effect relationship between individualized air pollution exposure and various adverse respiratory effects.

References and Notes

1. Schwarts J. Air pollution and daily mortality: a review and meta analysis. Environ Res 64:36–52 (1994).
2. Bates DV. Health indices of the adverse effects of air pollution: the question of coherence. Environ Res 59:336–349 (1992).
3. Thurstone GD, Ito K, Hayes CG, Bates DV, Lippmann M. Respiratory hospital admissions and summertime haze air pollution in Toronto, Ontario: consideration of the role of acid aerosols. Environ Res 65:271–290 (1994).
4. Brunekreef B, Dockery DW, Krzyzanowski M. Epidemiologic studies on short-term effects of low levels of major ambient air pollution components. Environ Health Perspect 103(suppl 2):3–13 (1995).
5. Romieu I, Lugo MC, Velasco SR, Sanchez S, Meneses F, Hernandez M. Air pollution and school absenteeism among children in Mexico City. Am J Epidemiol 136:1524–1531 (1992).
6. Chan CC, Hwang JS, Wang JD. Characterization of air pollution profiles for rural, urban and petrochemical communities. (Submitted)
7. WHO. WHO children's questionnaire and notes. In: Methods for Cohort Studies of Chronic Airflow Limitation (Florey CDV, Leeder SR, eds). Copenhagen: World Health Organization Regional Office for Europe, 1982;112–121.
8. Norušis MJ/SPSS Inc. SPSS for Windows: Base System User's Guide, Release 6.0. Chicago, IL:SPSS, Inc., 1993.
9. Norušis MJ/SPSS Inc. SPSS for Windows: Advanced Statistics, Release 6.0. Chicago, IL:SPSS, Inc., 1993.
10. Holland WW, Bennett AE, Cameron IR, Florey CDV, Leeder SR, Swan AV, Waller RE. Epidemiologic evidence and the United States air quality standards. Am J Epidemiol 111:458–459 (1980).
11. Samet JM. A historical and epidemiologic perspective on respiratory symptoms questionnaires. Am J Epidemiol 108:435–445 (1978).
12. Li CS, Hsu LY. Home dampness and childhood respiratory symptoms in a subtropical climate. Arch Environ Health 51:42–46 (1996).
13. Goren AI. Hellmann S. Respiratory conditions among schoolchildren and their relationship to environmental tobacco smoke and other combustion products. Arch Environ Health 50:112–118 (1995).
14. Pope CA, Dockery DW, Spengler JD, Raizenne ME. Respiratory health and PM_{10} pollution: a daily time–series analysis. Am Rev Respir Dis 144:668–674 (1991).
15. Mutius EV, Sherrill DL, Fritzsch C, Martinez FD, Lebowitz MD. Air pollution and upper respiratory symptoms in children from East Germany. Eur Respir J 8:723–728 (1995).
16. Schmitzberger R, Rhomberg K, Buchele H, Puchegger R, Schmitzberger ND, Kemmler G, Panosch B. Effects of air pollution on the respiratory tract of children. Pediatr Pulmonol 15:68–74 (1993).
17. Ostro BD, Lipsett MJ, Wiener MB, Selner JC. Asthmatic responses to airborne acid aerosols. Am J Public Health 81:694–702 (1991).
18. Wjst M, Reitmeir P, Dold S, Wulff A, Nicolai T, von Loeffelholz-Colberg EF, von Mutius E. Road traffic and adverse effects on respiratory health in children. BMJ 307:596–600 (1993).
19. Oosterlee A, Drijver M, Lebret E, Brunekreef B. Chronic respiratory symptoms in children and adults living along streets with high traffic density. Occup Environ Med 53:241–247 (1996).